Gap Analysis for Swift Creek Reservoir Watershed Management Master Plan

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1. Introduction

Chesterfield County's Watershed Management Master Plan and Maintenance Program for the Swift Creek Reservoir Watershed (Master Plan) is in its 6th year of implementation. With a goal of reviewing the plan's performance, improving it, as needed, and meeting new regulatory requirements that were developed after the original Master Plan was adopted in 2000, CH2M HILL performed a gap analysis. The gap analysis identifies information gaps that may provide opportunities to further protect the Upper Swift Creek Reservoir and to update and refine the Master Plan. It is not intended to be a comprehensive update to the Master Plan. The purpose of this technical memorandum (TM) is to summarize the results of gap analysis in several key areas of the Master Plan.

The gap analysis included the following:

- Sources of total phosphorus (TP) not included in the original modeling effort;
- TP removal mechanisms not accounted for in the original modeling effort;
- County ordinances that could impact development practices, and consequently TP loads to the reservoir;
- A comparison of monitoring data with model output; and
- The adequacy of the pro rata fee as a funding source.

Conclusions and recommendations are provided in Section 6.

2. Gap Analysis of the Total Phosphorus Model

To date, modeling of total phosphorus (TP) loading to the Upper Swift Creek Reservoir has been conducted with the P-8 Urban Catchment Model (P-8). P-8 has been used to generate annual loads for each of the ten tributaries as well as annual loads from those areas that discharge directly to the reservoir. Most of the BMP modeling was accomplished in P-8, either as part of the larger tributary model or in a smaller segment used to test various alternatives to BMP siting and size as they are proposed by different development projects. The impacts to the reservoir are determined by inputting the sum of the annual TP loads and the sum of the annual flow determined by the P-8 watershed model into the Reckhow model, a spreadsheet model that predicts the median in-lake TP concentration.

Previous modeling efforts has focused on the sources of TP load resulting from land development and have not considered additional sources that have the potential to be significant contributors of TP to the reservoir. P-8 is designed to model stormwater runoff from various watersheds and route stormwater through BMPs. It is not a comprehensive watershed model that is capable of including other TP sources. Three potential phosphorus inputs have surfaced as potentially significant since the previous modeling was conducted: stream erosion, septic systems, and phosphorus cycling in the reservoir. These potential phosphorus sources are described in this gap analysis, along with a general assessment of the magnitude of impact. Additionally, one important TP removal mechanism, undocumented BMPs, is also addressed.

2.1. Stream Erosion

The previous modeling effort estimated phosphorus loads originating from surface runoff, but did not consider the possible phosphorus load that might be associated with stream channel erosion. Stream assessments conducted as part of the County's Watershed Assessment and Stream Protection (WASP) program have identified several areas of significant stream bank erosion. High stormwater-related flows from future development within the watershed can also result in additional stream bank erosion. This can be especially true if stormwater flows are being controlled at regional ponds, located downstream of headwater streams. This leaves the stream channels upstream of the ponds vulnerable to the high velocities of stormwater flows. Delays in obtaining agency approval of regional ponds also have the potential to exacerbate streambank erosion.

The amount of phosphorus load coming from the stream banks is difficult to determine. It is dependant on two main variables: how much sediment load is being delivered through stream bed and bank erosion, and how much phosphorus is in the native sediments that are eroding.

The first gap that would need to be evaluated in Swift Creek Reservoir Watershed is the volume of soil lost to stream bank erosion each year. There are few methods available to estimate sediment load originating from stream bank and bed erosion, and most are extremely labor intensive.

One method for estimating sediment loads originating from stream channels is the Watershed Assessment of River Stability & Sediment Supply (WARSSS) approach, developed by Dave Rosgen. It has been used by the US EPA to evaluate sediment TMDLs (http://www.epa.gov/warsss/index.htm). It is broken into 3 phases:

- Phase 1 - Reconnaissance Level Assessment (RLA)
- Phase 2 - Rapid Resource Inventory for Sediment and Stability Consequence (RRISSC)

- Phase 3 - Prediction Level Assessment (PLA)

The intent of this approach is to conduct a desktop evaluation of the watershed based on sensitive land uses, slopes, and soils to identify the most likely areas of sediment loads and prioritize the areas of more intensive assessment. The field assessments conducted as part of Phase 3 are based on an estimated a Bank Erosion Hazard Index (BEHI) and Near-Bank Shear Stress (NBSS) condition. Based on regional curves, these values can be extrapolated to an estimated feet of bank erosion per year, which can be converted into a volume of sediment per year. Unfortunately, to date there are no regional curves developed for this part of the country. Therefore, field monitoring would be required to produce a realistic estimate of stream erosion.

Generally this approach takes several months, depending on the amount of field work that is needed. However it may be possible that the work already conducted as part of the County's WASP program could be used within the context of the WARSSS approach to estimate sediment loads from the stream channels.

The second question to be resolved is the amount of phosphorus associated with the sediments in the stream banks. One study in Mississippi estimated total phosphorus in the stream banks to be approximately 200-300 mg/kg while in the stream bed, the total phosphorus load varied depending on the clay and silt content (Bledsoe, 2000). In general phosphorus content also decreased with depth along the bank profile. This phosphorus concentration can be compared to an average TP/TSS ratios in stream samples in Swift Creek Reservoir monitoring data of 991 mg TP/kg TSS. Stream bank soils within the County could be sampled and evaluated to determine a more appropriate TP content associated with stream bank erosion.

Another study in Minnesota estimated stream bank erosion and associated phosphorus loads (Sekely et. al, 2002). The study found that the derived erosion rate constant for slumping sites was 0.024 tons/sq. ft-yr. Streambank slumping accounted for 31% to 44% of the TSS load at the mouth of the Blue Earth River. The percentage of the TP load originating from streambank slumping was estimated to be from 7% to 10%, with annual contributions of 14 to 19 tons. Although these studies are not local, they suggest that TP loads from stream bank erosion may be significant.

There are approximately 1,000,000 linear feet of channel in the Upper Swift Creek Reservoir Watershed. If it is assumed that approximately 30% of the channels in Swift Creek Reservoir Watershed are eroding, with an average bank height of 3 feet, the total sediment load to the reservoir would be 21,600 ton/yr, based on a rate of 0.024 tons/sq ft-yr . Applying a phosphorus load of 250 mg/kg, the total phosphorus load from stream bank erosion would be approximately 5.4 tons/year or 10,800 lb TP/yr. As a means of comparison, the 2004 watershed model predicted approximately 14,500 lb TP/yr load from runoff throughout the watershed based on existing land use. Uncontrolled future land is predicted to generate over 44,000 lb TP/yr.

Based on the initial estimates of phosphorus load, stream restoration should be conducted to maintain the total phosphorus concentrations in the reservoir. However before credit can be taken for the phosphorus load reduction from stream restoration, the total load associated with the original bank erosion needs to be included in the load estimates.

Given the large portion of the phosphorus load that could be originating from stream bank erosion it is recommended that a more accurate estimate be developed. This would include collecting a few stream bank samples to determine phosphorus content in Chesterfield County stream banks, and estimating stream bank erosion per year, based on information collected during the WASP field work. It would also be appropriate to begin stream bank erosion monitoring, to measure bank erosion at select locations in the county, in order to validate the initial estimates. This would involve surveying bank profiles at several cross-sections on an annual basis to determine the volume of soil erosion occurring.

2.2. Septic Systems

Discharge from septic systems may be a source of TP to the reservoir. Typical TP concentrations in septic tank effluent range from 10 – 20.5 mg/L (on-site literature search from Virginia Department of Health (VDH) website, 1999, www.vdh.state.va.us/onsite/text/litt-sur.htm)

Typically, TP is removed from the effluent stream in the soil field (85-95%). However, over time, the soil will become saturated with TP, allowing for TP migration through the soil to surface waters. Additionally, lack of pumping out of septic tanks and other factors can lead to system failures that result in the direct discharge of effluent to the surface where it can be washed off into the tributaries and reservoir. Assuming a typical system serves a household of four people with a per capita daily flow of 80 gpd, a failing system will discharge approximately 14.6 lb TP / year, if not repaired. A functioning system could still discharge 1.5 lb TP/year, assuming a 90 percent removal.

It is uncertain at this time how much of this phosphorus reaches the reservoir. Estimates will be dependent on typical lot layout, proximity to a tributary via ditch, stream or stormwater conveyance, length of flow through a buffer area, and slope of flow path. Total annual loads from all septic systems also will depend on the number of systems in the watershed and the failure rate of those systems. Chesterfield County has an aggressive on-site pump out ordinance on the books, requiring homeowners to pump out their septic tanks once every five years. However, it is uncertain how this ordinance is enforced or checked for compliance.

2.3. Phosphorus Cycling in Reservoir

Another part of the reservoir's phosphorus budget that has not been considered is the internal load due to phosphorus release from bottom sediments. This occurs in the summer, as the reservoir thermally stratifies and an anoxic zone is established in the bottom waters. With little or no dissolved oxygen, phosphorus is released from the reservoir bottom. At turnover, when the reservoir becomes mixed, a portion of the phosphorus released from the sediment precipitates and returns to the sediment, a portion of the phosphorus leaves the reservoir via the spillway or the water treatment plant intake, and the remainder stays in the water column, presumably increasing the overall concentration in the reservoir.

Determining the amount of internal loading can be difficult, as most methods are an indirect calculation. The best method typically involves seasonal measurements of phosphorus and dissolved oxygen in the water column, coupled with development of a reservoir model with a sediment compartment that simulates sediment oxygen demand and release of reduced compounds. The calculation methods include the following:

- Estimates using the reservoir's total phosphorus budget. These methods assume that every other component of the reservoir's budget can be independently estimated.
- Estimates using water quality data. These methods usually depend on either the TP concentrations observed in the hypolimnion or the TP concentrations observed at fall turnover.
- Estimates based on TP release rates. The release rates are observed in laboratory conditions and then applied to the entire reservoir.

2.4. Previously Undocumented BMPs

Unlike the preceding parts of Section 2, this section discusses a significant TP removal mechanism not a TP source. This mechanism is the undocumented BMP. Undocumented BMPs are existing BMPs that have not been included in the previous modeling efforts. A brief survey of the Little Tomahawk Creek watershed by County staff revealed up to seventeen previously unidentified BMPs. Preliminary data indicates the totals for the entire reservoir watershed could exceed 70 BMPs. Most of the BMPs are small dry or wet ponds with limited drainage areas. Many were constructed by VDOT other public agencies, and developers.

BMP design characteristics, such as drainage area and TP removal for many, if not all of these BMPs remain unidentified. However, if each BMP removed an average of 4-5 lb/yr TP, then the preliminary ones identified may be removing 280-350 lb/yr. This is the equivalent of a typical regional pond.

3. Gap Analysis of County Ordinances

3.1. Purpose and Method

The purpose of this analysis is to review and analyze several major County Ordinances for potential modifications to assist in the reduction of TP loads. Examples include tree preservation and minimizing impervious surfaces. This is a high level analysis meant to show where changes can be readily made.

The analysis involved researching current County Ordinances (listed below) and identifying the sections that, if modified, may result in either less runoff or total phosphorus reduction from the runoff. The County Ordinances that were reviewed as part of this analysis include the following:

- Chapter 17 Subdivision of Land, Article III. Standards, Division 1. Minimum Standards and Improvements Required
- Chapter 17 Subdivision of Land, Article III. Standards, Division 2. Street Standards
- Chapter 19 Zoning. Article III. Districts, Division 3. Floodplain Districts.
- Chapter 19 Zoning. Article III. Districts, Division 7 – 10 (choice of 1-2 typical Residential Districts.)

- Chapter 19 Zoning. Article III. Districts, Division 16 – 21 (choice of 1-2 typical Non-residential Districts.)
- Chapter 19 Zoning. Article IV. Countywide Development Standards, Division 4 Chesapeake Bay Preservation Areas
- Chapter 19 Zoning. Article IV. Countywide Development Standards, Division 5 Upper Swift Creek Watershed.
- Chapter 19 Zoning. Article IV. Countywide Development Standards, Division 6 Stormwater Management and Best Management Practice Basins
- Chapter 19 Zoning. Article VII. Development Standards Manual, Division 2. Development Requirements – Residential, Townhouse Residential, Multifamily Residential
- Chapter 19 Zoning. Article VII. Development Standards Manual, Division 3. Development Requirements – Office, Commercial, and Industrial

In addition, the requirements set forth by these County Ordinances were compared to the following standards, principals, and/or guidelines:

- Center for Watershed Protection. "Better Site Design--An Assessment of the Better Site Design Principles for Communities Implementing Virginia's Chesapeake Bay Preservation Act."

- Center for Watershed Protection. "Site Planning Model Development Principles"

3.2. Compare County Ordinance to Design Principals for Communities Implementing Virginia's Chesapeake Bay Preservation Act

When comparing pre- and post- development conditions, the water balance typically is disrupted relative to the level of disruption to the natural habitat. Post-development impacts include increased surface runoff, and reduced interflow and baseflow. As a result, total phosphorus loadings increases because the increased impervious area does not filter phosphorus, which was previously filtered by vegetated habitats.

Depending on a locality's site design process, disruption to the natural habitat and phosphorus loadings can be reduced. Table 3-1 shows development principles compared to general performance criteria. Specific gaps between existing County Ordinances and the recommended principles are identified in Section 3.3.

TABLE 3-1
Development Principles Compared to General Performance Criteria

Principle	Model Development Principle	Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surface	TP Reduction Potential
1	Native Plant & Tree Conservation	X	X		Medium
2	Minimized Clearing & Grading	X	X		Medium
3	Open Space Design	X	X		Medium
4	Shorter Setbacks & Frontages	X	X	X	High
5	Common Walkways			X	Medium
6	Shared Driveways			X	Medium

TABLE 3-1
Development Principles Compared to General Performance Criteria

Principle	Model Development Principle	Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surface	TP Reduction Potential
7	Narrower Streets	X	X	X	High
8	Shorter Streets			X	Medium
9	Narrower Right-of-Way Widths	X	X		Medium
10	Smaller & Landscaped Cul-de-Sacs			X	Low
11	Vegetated Open Channels			X	Medium
12	Reduced Parking Ratios	X	X	X	High
13	Mass Transit & Shared Parking			X	Low
14	Less Parking Lot Imperviousness	X	X	X	High
15	Structured Parking	X	X	X	High
16	Treated Parking Lot Runoff	X			Medium

Source: Virginia Chesapeake Bay Local Assistance Department, 1999

3.3. Compare County Ordinance to CWP Site Planning Model Development Principles

The following section compares the CWP Site Planning Model Development to County Ordinances. These principles are simplified design objectives. The focus of the comparison is primarily on whether or not County codes and ordinances address planning and design elements identified in the CWP Site Planning Model, rather than the effectiveness of their implementation. Additional evaluation of the effectiveness of implementation is recommended. CWP provides a Codes and Ordinance Worksheet that helps evaluate specific local conditions (see Section 3.4)

Residential Streets and Parking Lots (Habitat for Cars)

1. Design residential streets for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on traffic volume.

> Chapter 17 Subdivision of Land, Article III. Standards, Division 2. Street Standards sets forth provision for the arrangement of local streets to "[p]ermit effective stormwater drainage and efficient utility systems."
>
> Regarding the arrangement of streets, "Subdivision layouts shall be arranged to maintain proper relationship to topographical conditions and natural terrain features such as streams and existing vegetation."

The ordinances reviewed address "minimum required pavement", but not necessarily in the context of reducing impervious area. CWP recommends street widths of 18-24 feet for low density residential development streets with less than 500 average daily trips. County standards are to comply with VDOT minimum standards.

2. Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.

> Section 17-76 encourages arrangement of streets to "to maintain proper relationship to topographical conditions and natural terrain features such as streams and existing vegetation" and "Permit effective stormwater drainage and efficient utility systems".

The focus of the ordinance is not on reducing the total street length or on increasing the number of homes per unit length.

3. Minimize the number of standard residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.

> Section 17-79 requires "Cul-de-sac streets shall not provide access to more than 50 lots.Cul-de-sac streets with less than 25 lots shall provide a minimum pavement radius of 35 feet. Cul-de-sac streets with greater than 25 lots shall provide a minimum pavement radius of 45 feet."

CWP recommends a 35 foot maximum radius of cul-de-sacs but finds 36-45 foot radius acceptable.

4. Where density, topography, soils, and slope permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.

> Section 17-76 requires "Curb and gutter shall be required on all local streets in all subdivisions, where the average lot has less than 100 feet of street frontage. The calculation excludes those lots fronting on the radial terminus of a cul-de-sac. Curb and gutter installation may be waived, in whole or in part, by the director of planning or planning commission to preserve the existing neighborhood local street drainage method.

Additionally, ordinances do not refer to use of vegetated open channels. VDOT does not require in Appendix B of the Road Design Manual (VDOT, 2005). Section B-13, paragraph G states "The department does not require the use of curb and gutter on subdivision streets but recognizes that it is an acceptable design alternative and preferred in high density developments."

5. The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance taking into account local and national experience to see if lower ratios are warranted and feasible.

Ordinances do not refer to parking ratios.

6. Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.

County Ordinances that were reviewed have various provisions for conditions that would allow for reduced number of parking spaces.

7. Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in spillover parking areas where possible.

CWP recommends minimum stall widths (9 ft or less) and lengths (18 ft or less) for standard parking spaces, at least 30% of spaces at larger commercial parking lots be required to be for compact cars, and the use of pervious materials for spillover parking. Ordinances do not address this principle.

8. Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.

Ordinances do not address this principle.

9. Wherever possible, provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

Ordinances do not specifically call for use of these BMPs. However, their use is not precluded to treat parking lot runoff. The County also needs to consider how to encourage better use of green space within parking lots. Common practice is to create small, vegetated islands throughout a parking lot. These islands are typically green space surrounded by curbing with elevations above the surrounding parking lot. The combination of curb and higher elevation disconnects the islands from the parking lot runoff. Additionally, the islands' small size and construction methods lead to compacted soils within each island. Compacted soils are poor candidates to provide beneficial infiltration of runoff.

All of the factors described above limit the value of parking lot islands from a stormwater perspective. Many islands also require irrigation to maintain their vegetation. Frequent irrigation increase demands on groundwater resources as well as County water supply.

Lot Development (Habitat for People)

10. Advocate open space design development incorporating smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

Ordinances address open space, but do not require smaller lot sizes.

11. Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.

CWP recommends the following:

- Use of irregular shaped lots.
- For one half acre residential lots, a minimum front setback of 20 feet or less, a minimum rear setback of 20 feet or less, a minimum side setback of 8 feet or less, and a minimum frontage distance of 80 feet or less.

It should be noted that these setback distances need to be coupled with open space preservation within a development in order to reduce the overall imperviousness of the development. Ordinances address setbacks and frontages, but do not appear to be focused on reducing road length or total imperviousness. Other potential changes to ordinances include larger backyard setbacks and requirements for more lots to drain to the back of the lot, both of which would result in a longer flow path for runoff, creating more opportunities for interception and infiltration.

12. Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.

CWP recommends the following:

- Minimum sidewalk width of 4 feet.
- Sidewalks on one side of residential streets.
- Sidewalks sloped to drain to the front yard.
- Alternate pedestrian networks substituted for sidewalks (i.e. trails through common areas).

Ordinances address sidewalks, but do not require minimum widths, single sidewalks, or common walkways. VDOT requires sidewalks that are 5 feet in width but allows sidewalks as narrow as 3 feet as long as appropriate ADA passing areas are included. Non-compliant sidewalks are allowed by VDOT, however not only will VDOT not maintain non-compliant sidewalks, it requires a permit stating that the County will maintain the sidewalks. VDOT also requires spacing between the sidewalk and curb and gutter (3-6 ft).

13. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.

Ordinances address drives, but are not necessarily specific to minimizing impervious surfaces..

14. Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.

Where applicable, Ordinances specify homeowner associations (HOA) shall own and maintain commonly held open space and recreation facilities. However, the ordinances do not address how the open space will be managed with regard to such actions as reducing impervious surfaces, vegetated buffers, or mowing in buffers.

15. Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.

Not addressed by Ordinances. Many homes are known to have roof leaders that are piped directly to the gutter or the storm sewer or discharge to the property’s driveway which is sloped to the road.

Conservation of Natural Areas (Habitat for Nature)

16. Create a variable width, naturally vegetated buffer system along all perennial streams that also encompasses critical environmental features such as the 100-year floodplain, steep slopes, and freshwater wetlands.

Buffers are addressed in Division 4. Chesapeake Bay Preservation Areas (CBPA). However, there appear to be loopholes in the ordinance allowing variances impacting the buffer to be issued.

17. The riparian stream buffer should be preserved or restored with native vegetation. The buffer system should be maintained through the plan review delineation, construction, and post-development stages.

Addressed in Division 4. Chesapeake Bay Preservation Areas for Water Quality Impact Assessments and Resource Protection Area Restoration Plans, but only to maximum extent practical. There appear to be loopholes in the ordinance allowing variances impacting the buffer to be issued.

18. Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.

Addressed in Division 4. Chesapeake Bay Preservation Areas for Water Quality Impact Assessments and Resource Protection Area Restoration Plans, but only to maximum extent practical. Also addressed in stormwater management ordinance. No limits are required for those areas outside of the CBPA. No requirements for preserving green space.

19. Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas.

Not addressed by Ordinances.

20. Incentives and flexibility in the form of density compensation, buffer averaging, property tax reduction, stormwater credits, and by-right open space development should be encouraged to promote conservation of stream buffers, forests, meadows, and other areas of environmental value. In addition, off-site mitigation consistent with locally adopted watershed plans should be encouraged.

Not addressed by Ordinances.

21. New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

Not addressed by Ordinances. However, stormwater discharges resulting in direct impacts to wetlands are regulated by Corps and DEQ.

Code and Ordinance Worksheet

CWP provides a worksheet that evaluates local conditions based development standards related to site planning ordinances. Based on the answers to specific questions (e.g., pavement width and right-of-way widths in residential zones), Table 3-2 shows the scoring scale and associated description. The worksheet is a helpful tool to further evaluate the effectiveness of County site planning in minimizing hydrologic and water quality impacts to the reservoir.

TABLE 3-2
Code and Ordinance Worksheet Score Scale

Score Scale	Description
90 - 100	Community has above-average provisions that promote the protection of streams, lakes and estuaries.
80 - 89	Local development rules are good, but could use minor adjustments or revisions in some areas.
70 - 79	Opportunities exist to improve development rules. Consider creating a site planning roundtable.
60 - 69	Development rules are likely inadequate to protect local aquatic resources. A site planning roundtable would be very useful.
less than 60	Development rules are definitely not environmentally friendly. Serious reform is needed.

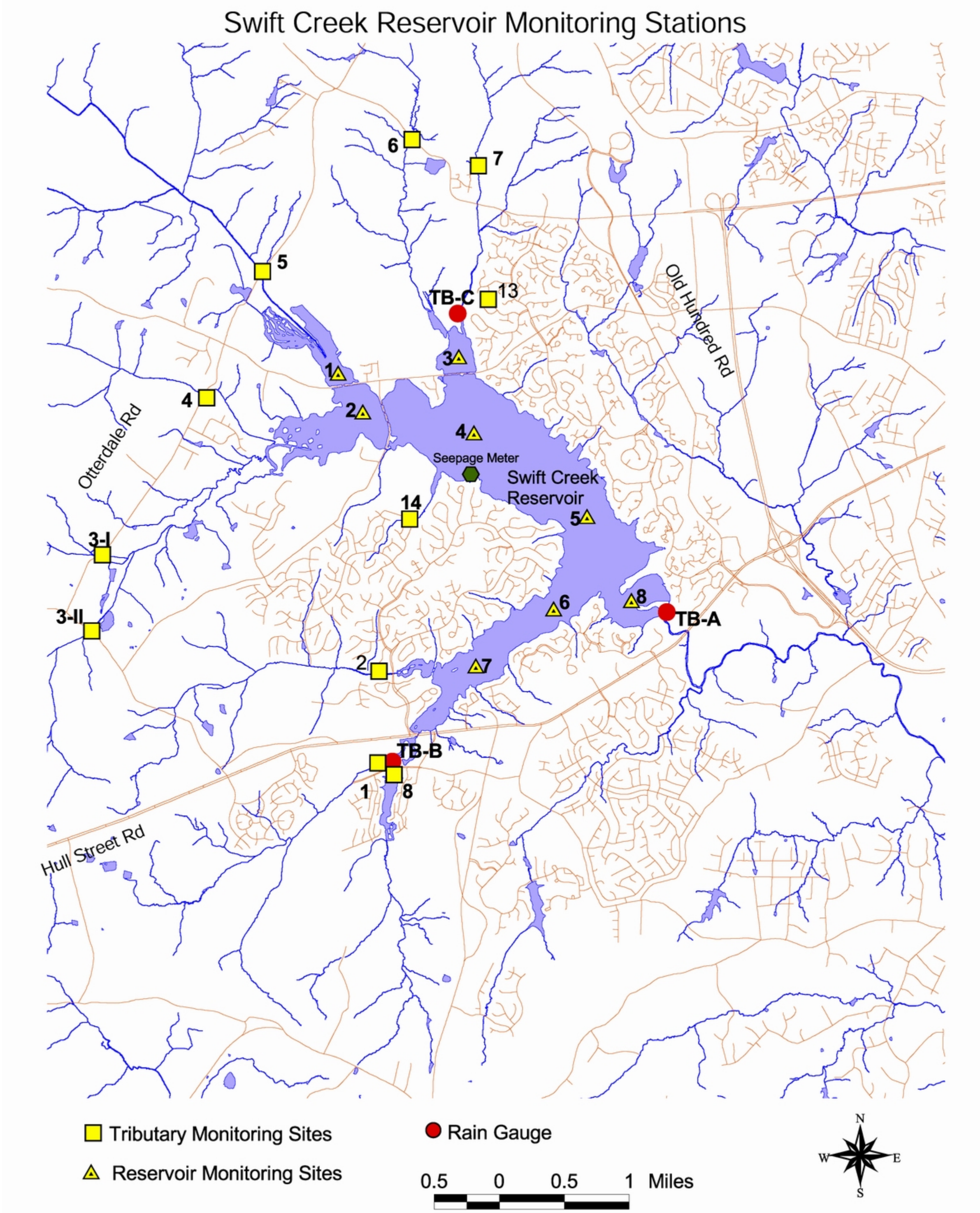
Source: http://www.cwp.org/COW_worksheet.htm

4. Monitoring Data versus Model Output

The comparison of the modeling and monitoring data was conducted for the year 2003. 2003 is the latest existing land use that has been modeled in the P-8 tributary models. The gap analysis required two steps. The first step was to collect the 2003 monitoring data from the County. The data was originally collected by the Department of Utilities from eight sampling stations throughout the reservoir on a roughly two times each month basis (see Figure 1). The median TP concentration was calculated for time period of April to October, using all available data from the eight monitoring stations. This was to best compare the results of the Reckhow model which predicts the median in-lake TP concentration for the summer period. The result was 0.037 mg/L.

The second step was to update each of the tributary P-8 models by replacing the typical year precipitation file with the 2003 precipitation file. Land use did not change as the base models were previously set up with the 2003 land use. Each tributary model was run and the resulting annual flows and TP loads were compiled in a spreadsheet. The total loads and flows were then entered into the Reckhow model. The result was 0.037 mg/L. This is identical to the result of the analysis of the 2003 and well within the accuracy of the prediction. This indicates that the models' calibration is holding and there is no need to recalibrate the P-8 models at this time.

FIGURE 1
Swift Creek Reservoir Monitoring Locations



5. Gap Analysis of Funding

The pro-rata share program was enacted as part of the Master Plan to support the design and construction of regional BMPs identified in the Master Plan. The projected costs on which the fee is based include design, land acquisition, construction, wetland mitigation and other factors related to the implementation of the regional BMPs. While the pro-rata fee was indexed to reflect increasing changes in construction costs, it does not include other costs that have arisen in the years since the pro-rata fee was originally calculated. The most significant of these new costs is stream mitigation.

The requirement to mitigate streams directly impacted by stormwater facilities has become a regulatory requirement of the Army Corps of Engineers (ACOE) and DEQ. The regional BMPs identified in the Master Plan are estimated to have approximately 60,000 l.f. of stream impacts. These are direct impacts to the tributaries in the watershed that are the result of placing the regional BMPs online with the streams. They do not include impacts associated with development-related stream erosion or habitat degradation.

KCI (Bob Siegfried, 2006) has conducted a preliminary estimate of stream mitigation costs with the following values:

- Rural Streams - $177 per linear foot
- Urban Streams - $317 per linear foot
- Current Virginia Trust Fund - $400 per linear foot.

These costs include survey, design, construction, repair contingency, and post-construction monitoring. They do not incorporate stream attribute comparisons now required by regulatory agencies. Use of stream attribute comparisons are likely to raise mitigation requirements above the assumed ratio of one linear foot of stream restored per one linear foot of stream impacted. These costs also do not include land acquisition in the form of easements.

Assuming that all planned BMPs are constructed, and based on the costs above, the minimum additional cost to the pro-rata share is between $11 and $24 million in 2006 dollars. The pro-rata share was originally based on total capital costs approximately $36 million in 2000 dollars. Clearly, the additional requirement of stream mitigation will have a significant impact on the pro-rata fee. The County will need to consider how to factor in this additional cost on the fees previously collected.

Ordinances related to the pro rata fee also were analyzed to evaluate whether there is adequate flexibility to use pro rata fee revenues for stormwater management other than BMPs identified in the original Master Plan. The current pro rata fee ordinance states that payments received will be used only for the necessary engineering, related studies, land acquisition, and the construction of those facilities identified in the Master Plan. Construction of alternative facilities may require an ordinance change to permit the expenditure of pro rata fees on those facilities. However, stream mitigation may be permissible as a necessary action related to the construction of regional BMPs. The ordinance doesn’t clearly state the mechanism of changing the Master Plan BMPs that results in changing where the pro rata fees are spent.

Virginia enabling legislation requires that the pro rata fee from a specific development be applied to the fraction of water quality protection. As long as the payment is proportional it appears that the pro rata fee can be spent on any combination of BMPs.

Another possibility is to develop a three-tier approach to pro rata fees. The middle tier of fees would be based on the original pro rata fee. It represents a typical development within the watershed based on modeling and other assumptions. The lower tier of fees is the incentive tier. The incentive tier would be based on development that has lower impacts than the typical development. It could be based on the better site design principles described in Section 3, greater onsite control of stormwater, or other factors. The higher tier of fees is the disincentive tier. The disincentive tier would be based on development that has greater impacts than the typical development.

6. Gap Analysis of Watershed Management Plan

6.1. Pereniality Determinations

Changes in 2002 to Virginia's Bay Act regulations revised the resource protection area (RPA) description from the general and vague term of "shoreline" to water bodies with perennial flow. Under the old regulations, Chesterfield County had interpreted shoreline to be the solid stream lines on United States Geological Survey (USGS) topographic quad sheets. The revised regulations require the County to extend RPA protection to any stream that is determined to be perennial. Pereniality determinations are conducted on a stream by stream basis, mainly on first and second order streams that are located upstream of the original RPA boundaries established by the County.

The impact of the new pereniality determinations on the Watershed Management Plan and total phosphorus reduction is two fold. First, is the extension of riparian corridor management areas (RCMA) RPAs to areas originally identified as RCMA non-RPA. RCMA non-RPA are based on the floodplains in upper parts of each tributary watershed. RCMA non-RPAs are 25 foot setbacks from the 100-year floodplains that are located upstream of the original RPAs. Pereniality determinations have been carried out by the County on several streams that were previously associated with RCMA non-RPA controls. In most cases, the area of the new RPA matches or exceeds the area of the RCMA non-RPA. The widths of the new RPAs are based solely on stream size and may increase if wetlands adjacent to the stream are identified in the future.

Replacement of RCMA non-RPAs with RPAs results in lower TP annual loads because of increased areas of riparian buffer. RPAs are more restrictive than RCMA non-RPAs in regards to development within their boundaries. The result is lower total imperviousness, lowering annual runoff and the corresponding TP annual load. The RPAs are also considered more efficient in TP removal, due to longer flow paths as compared to the RCMA non-RPA.

The second impact on the Watershed Management Plan is to extend protection of the new RPAs to streams that were not previously protected. This reduces the future imperviousness, thus reducing future TP load. Extending RPAs also decreases the treatment required for TP removal by other methods. Previous modeling has indicated that buffers remove an average of 1.11 lb/yr per acre of buffer.

Pereniality determinations have added 245 ac of new RPA and transformed 210 ac RCMA-non-RPA in the Upper Swift Creek watershed. This represents a potential increase in TP removal of approximately 295 lb/yr, which is 2 percent of the annual TP load removal goal.

6.2. Preserving or Retrofitting Existing Ponds

GIS analysis of the watershed indicates that there are as many as 174 ponds in the Upper Swift Creek watershed. These ponds range in size from 0.01 ac to 10.81 ac. The GIS data layer does not include the intended purpose of the ponds, so one cannot differentiate between ponds built for stormwater management and ponds built for agricultural uses. The impact of preserving and/or retrofitting these existing ponds has not been assessed.

The first step is to assume that all ponds with surface areas of 0.5 ac or larger are candidates for preservation or retrofitting. There are 89 ponds with areas equal to or greater than 0.5 ac. If all of these ponds can be converted to stormwater facilities and each pond removes a minimal amount of TP (5 - 10 lb/year), then, collectively, the 89 ponds would remove 445 – 890 lb/year (3 – 6 percent of the annual TP load removal goal), or the equivalent of 2-3 regional ponds.

6.3. Onsite Pollutant Removal

The prospect of the elimination of the regional stormwater wet ponds (WBMPs and SBMPs) from the Watershed Management Plan has created the need to evaluate an alternative TP removal. The most suitable candidate, particularly in the short term is to require all new development to design and construct onsite BMPs to remove TP from the development's site only. This section describes the calculations for determining the onsite percent TP removal to be required of developers within the Upper Swift Creek watershed. It is anticipated that this requirement will be implemented by the County in the near future.

Table 6-1 summarizes the annual loads modeled at various times since 1999:

TABLE 6-1
Swift Creek Watershed Modeled Annul Loads

Land Use	Abbreviation	Annual Load (lb/yr)
1999 Existing	99ELU	12,189
2003 Existing	03ELU	14,547
Scenario B Future	SBFLU	44,398
Scenario B Goal to Maintain 0.05 mg/L	SBG	25,402

The total predicted load can be separated into three components; base load, orphan load, and future load. It is assumed that the 99ELU load is the base load. The average annual increase in TP loading from 1999 to 2003 can be calculated by taking the difference between 03ELU and 99ELU loads and dividing by four years. The difference between the two loads is 2358 lb/yr. Dividing this by 4, the average annual increase in TP loading from 1999-2003 is

589.5 lb/yr/yr. The orphan load is defined as any increase in load from 1999 to 2006. The orphan load is calculated as 2,358 lb/yr + 3 yr*589.5 lb/yr/yr which equals 4,127 lb/yr.

Assuming that 30% of the orphan load is removed by way of unidentified existing BMPs and other methods, the remaining load, the net orphan load, is 2,889 lb/yr. The 30% removal needs to be verified as other data is collected and analyzed. Adding the baseload with the net orphan load results in a total load of 15,078 lb/yr, approximately 10,000 lb/yr less than the Scenario B goal.

The future load is defined as the difference between SBFLU and the sum of the 99ELU and the total orphan load (the current load) or 44,398 lb/yr - (12,189 lb/yr + 4,127 lb/yr). The result is 28,082 lb/yr. The difference between the Scenario B goal and the sum of the baseload and the net orphan load is the amount of future load that can reach the reservoir and still maintain reservoir water quality. The calculation is 25,402 lb/yr - 15,078 lb/yr or 10,324 lb/yr. The fraction of future load that needs to be reduced to achieve the Scenario B goal is 100%*[1 - (10,324 lb/yr/28,082 lb/yr)] or roughly 65 percent.

The goal of 25,402 lb/yr can be achieved by requiring all new development to remove 65% of the annual total phosphorus load generated and the removal of an additional 1,238 lb/yr from BMP retrofits and other TP removal measures.

7. Summary

Table 7-1 is a summary of the information gaps discussed in Sections 2 through 5 as well as preliminary recommendations to close those gaps.

TABLE 7-1
Information Gap Summary

Information Gap Category	Information Gap(s)	Increase or Decrease Phosphorus Load?	Recommendations
Stream Erosion	Volume of Annual Soil Lost to Stream Bank Erosion TP Content of Stream Bank Soils	Increase by eliminating knowledge gap.	Estimate sediment loads using existing data collected during WASP assessments, and approach outlined in WARSSS or similar method. Monitor select stream banks to measure annual stream bank erosion to validate erosion estimates. Sample and evaluate stream bank soils within the watershed to determine a TP content associated with stream bank erosion Determine annual TP loads from stream bank erosion for existing and future land use conditions.
		Decrease.	Determine methods for reducing steam bank erosion TP load and apply to calculations.
Septic Systems	Number of Septic Systems Septic System Failure Rate Delivery Estimates	Increase by eliminating knowledge gap.	Work with Health Department to determine number and location of septic systems in each tributary watershed Work with Health Department to determine the number of septic systems that are consistent with future development and water and sewer master plans. Determine appropriate septic system failure rates for existing and future conditions and calculate the annual loading to the reservoir of septic systems.

TABLE 7-1
Information Gap Summary

Information Gap Category	Information Gap(s)	Increase or Decrease Phosphorus Load?	Recommendations
Phosphorus Cycling in Reservoir	Analysis of Reservoir TP, DO, and Temp Data Model of TP Release from Sediment	Increase by eliminating knowledge gap.	Use one of the following to determine the order of magnitude of TP release: • Estimates using the reservoir's total phosphorus budget. • Estimates using water quality data. • Estimates based on TP release rates. If the TP release order of magnitude is comparable to other sources (runoff, etc), then consider a more accurate model or calculation.
Previously Undocumented BMPs	Location	Decrease by eliminating knowledge gap.	Use the same approach as used in the Little Tomahawk Creek watershed. County staff identify each facility, GPS its outer boundary, and input GPS data into GIS.
	Data including the following: • Drainage Area • Design data • Design TP removals		Find design data in plans submitted to County for approval. Start data base of BMPs to include design data, location, surface area, etc for future accounting/TP removal calculations. Incorporate TP removals into watershed wide calculations as they are determined. or revised modeling.
		Decrease.	Incorporate TP removals into revised watershed modeling when this becomes necessary in the future.

TABLE 7-1
Information Gap Summary

Information Gap Category	Information Gap(s)	Increase or Decrease Phosphorus Load?	Recommendations
Ordinances Supporting Lower TP Loads	Native Plant and Tree Conservation	Decrease.	Develop appropriate standard for native plant and tree conservation within the CPBA and other green spaces in the watershed. Standard cannot be stand alone but incorporated with other standards.
	Minimized Clearing & Grading	Decrease.	Develop appropriate standards for clearing and grading within the watershed whose goal is the maximum preservation of undisturbed soils and vegetation. Set clear preservation goals. Close loopholes in existing ordinances.
	Open Space Design. Ordinances address open space but not as an offset to higher per lot imperviousness on smaller lots.	Decrease.	Develop more appropriate ordinances that encourage and provide standards for open space design. This cannot be stand alone but incorporated with other standards.
	Shorter Setbacks & Frontages. While ordinances address setbacks and frontages, they do not appear to be focused on reducing road length or total imperviousness.	Decrease.	Change ordinances to allow for shorter setbacks and frontages for residential lots. This cannot be stand alone but incorporated with other standards as green space needs to be set aside to offset higher per lot imperviousness.
	Narrower Sidewalks and Common Walkways. Ordinances address sidewalks in a limited manner but do not require minimum widths, single sidewalks, or common walkways.	Decrease.	Change ordinances to require only one sidewalk per residential street, minimum sidewalk width, and common walkways.
	Shared Driveways Not addressed by County ordinances reviewed.	Decrease.	Change ordinances to encourage shared driveways and to set standards for smaller driveways.

TABLE 7-1
Information Gap Summary

Information Gap Category	Information Gap(s)	Increase or Decrease Phosphorus Load?	Recommendations
Ordinances Supporting Lower TP Loads	Narrower Streets. County standards are to comply with VDOT minimum standards but do not require a minimum width.	Decrease as street width decreases.	Determine and promulgate minimum street width standards for various average daily trip levels and compare to VDOT standards.
	Shorter Streets	Decrease as street length decreases.	Determine best way to promote shorter streets, either through a design standard or through the plan review process.
	Narrower Right-of-Way. CWP recommends right of way widths of less than 45 feet. County standards are to comply with VDOT minimum standards.	Decrease as ROW decreases.	Determine and promulgate right of way widths for watershed streets.
	Smaller & Landscaped Cul-de-Sacs.	Decrease as cul de sac radius decreases.	Determine and promulgate a cul-de sac radius standard, preferably between 35 and 40 feet.
	Vegetated Open Channels. Ordinances do not refer to use of vegetated open channels. Ordinances require curb and gutter for narrower lot fronts (less than 100 ft), negating the goal of shorter frontages (see above).	Decrease.	Adopt a design standard for open channel design. Relax the requirement for curb and gutter for narrow lots in the watershed.
	Reduced Parking Ratios. Ordinances do not address parking ratios.	Decreases as parking ratios decrease..	Determine appropriate parking ratio for watershed land uses.
	Mass Transit & Shared Parking. County ordinances describe conditions that would allow for reduced number of parking spaces.	Neutral.	None.

TABLE 7-1
Information Gap Summary

Information Gap Category	Information Gap(s)	Increase or Decrease Phosphorus Load?	Recommendations
Ordinances Supporting Lower TP Loads	Less Parking Lot Imperviousness. Not addressed by County ordinances reviewed.	Decrease.	Develop standards that reduce parking lot impervious by emphasizing minimum stall width and length for standard parking spaces, compact car parking space requirements, and the use of pervious materials for spill over parking areas.
	Structured Parking. Not addressed by County ordinances reviewed.	Neutral, depends on outcome.	Determine if there is a need to address structured parking within the watershed.
	Treated Parking Lot Runoff Ordinances do not specifically comment on the use of specific BMPs.	Decrease.	Determine best suite of BMPs for treating parking lot runoff in watershed and promulgate requirements for their use.
Funding	Cost of Mitigating Stream Impacts	Decrease.	If BMPs in current plan can be built, determine cost of stream mitigation and incorporate into pro rata fee.
	No Incentives or Disincentives in Current Pro Rata Fee Structure	Decrease if higher costs alter behavior.	Investigate the possibility of a three tier pro rata fee system. Items to research include legality under VA legislation and cost of each of the three tiers.
	Cost of Implementing Greater Number of Small BMPs	Neutral.	If the Master Plan is revised, determine the following: • Pollutant reduction requirements that need to be funded • Cost of new BMP mix. • Pro rata fee to support those costs.
	Flexibility of Pro Rata Ordinance to Support Revisions to Master Plan	Neutral.	Revise the ordinance to not require future ordinance changes when the Master Plan is revised.

TABLE 7-1
Information Gap Summary

Information Gap Category	Information Gap(s)	Increase or Decrease Phosphorus Load?	Recommendations
Watershed Management Plan	Pereniality Determinations	Decrease as long as RPA increase.	Continue pereniality determinations. Require stormwater to flow through the buffer as sheet flow where ever possible. Increase buffer effectiveness by removing pipes and ditches that bypass buffer and by restoring buffer vegetation in degraded areas.
	Preserving or Retrofitting Existing Ponds	Decrease.	Inventory largest ponds and assess stormwater BMP potential. Require the preservation and retrofit of existing ponds where ever possible. Refine pollutant removal calculations.
	Onsite Pollutant Removal	Decrease.	Refine onsite removal requirements based on the following: • Incorporation of better site design and LID • Complete accounting of existing BMP TP removal • Pereniality determinations throughout the watershed

8. References

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